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OPTIMIZATION OF BRAIDED REINFORCED COMPOSITE RODS

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ABSTRACT

This work described the development of braided reinforced composite rods for concrete reinforcement. The research study aims to analyse the influence of braided fabrics geometry on the core reinforced braided fabrics mechanical behaviour. Moreover, this study intends to identify the influence of different fiber types used as core reinforcement and of testing conditions on the mechanical properties of braided fabric composite rods,

KEYWORDS

Concrete, fiber reinforced composite materials, core reinforced braided fabric, core reinforced braided composite rod.

1. INTRODUCTION

Typically, FRP rods are produced by pultrusion, which is a well-known manufacturing method in fabricating FRP products with a constant cross section. In the pultrusion process, the longitudinal fibers are drawn through a resin bath and then passed through a die, which gives the rod its final shape (Kadioglu et al, 2005). Therefore, FRP rods present smooth surface and, when used as internal reinforcement for concrete, the bond at the interface between an FRP rod and concrete is of paramount importance. The bond behaviour will have a direct influence on both the serviceability and ultimate limit. To improve bond behaviour FRP-concrete, a surface treatment is required to introduce deformations on the rod surface, and two different approaches can be considered: deformation of the surface, due to the presence of ribs or indents or providing deformations in the outer resin layer, or surface treatments, such as sand blasting or epoxy-coated sand (Lees, 2001). Besides pultrusion, FRP rods can also be produced using braiding techniques (Soebroto et al, 1990). Braiding is a low cost technique allowing in-plane multiaxial orientation, conformability, excellent damage tolerance and core reinforcement. Moreover, braiding allows the production of ribbed structures and a wide range of mechanical properties may be improved when the core braided fabrics are reinforced with the appropriate type of fibers (Fangueiro et al, 2006).

2. EXPERIMENTAL WORK

The current work aims to understand the influence of braided fabrics geometry on the core reinforced braided fabrics mechanical behaviour. A study on the influence of the core reinforcement fiber type on the mechanical properties of the core reinforced braided fabrics and of composite rods has also been undertaken. Moreover, the work aims to understand the influence of testing conditions on the braided reinforced composite rods mechanical properties. The core reinforced braided fabrics have been produced on a vertical braiding machine. Braided reinforced composite rods have been produced by impregnating the core reinforced braided fabrics on a vinyl ester resin, in a single step.

2.1. Optimal braiding angle of core reinforced braided fabrics

Eight polyester bobbins were used to produce the braided structure and two rovings of glass fiber were used as core reinforcement. The braiding angle varies according to the braided fabric take-up rate. Braiding angles have been measured for each braided fabric produced and tensile tests were carried out. Fabric delivery speed and braiding angle are inversely proportional, as shown in Figure 1.

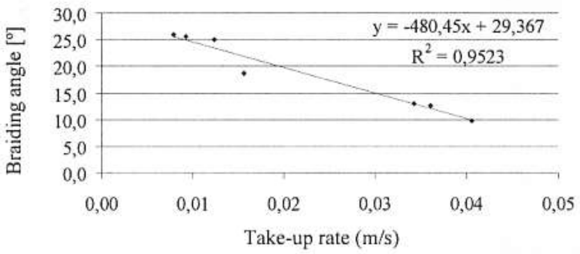

Figure 1: Influence of take-up rate on braiding angle.

Analysing the influence of the braiding angle on the ultimate tensile strength and on the extension at failure, it may be concluded that there is an inflection on the curve. The ultimate tensile strength and the extension at failure increase as the braiding angle increases up to 18.6°. For braiding angles higher than 25°, both the ultimate tensile strength and the extension at failure decrease as the braided angle increases (Figure 2).

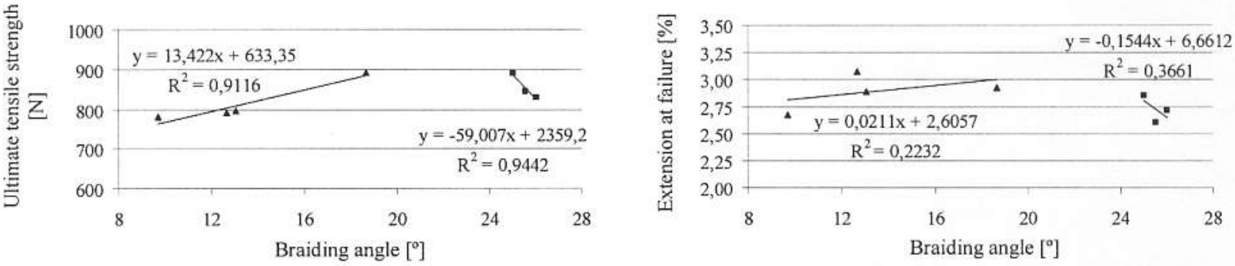

Figure 2: Influence of braiding angle on ultimate tensile strength and on extension at failure (mean values).

Based on the above results, it may be concluded that braided fabrics produced with 8 bobbins of polyester yarn, 2 of them with 4 yarns, and reinforced with 1800 Tex glass fiber roving as core reinforcement, lead to higher values of ultimate tensile strength and higher extensions at failure, when the braiding angles are between 18.6° and 25°.

2. 2. Core reinforced braided fabrics

Core reinforced braided fabrics were produced with a speed of production of 0,0156m/s. Glass, carbon, polyethylene and sisal fibers were used as core reinforcement. Tensile tests were carried out on the different core reinforced braided fabrics for different pre-loading conditions – 25N, 50N and 100N (Figures 4 and 5).

Braided fabrics reinforced with carbon fiber present the highest ultimate tensile stress (Figure 4); this does not seem to be significantly affected by the pre-loading conditions. Braided fabrics reinforced with polyethylene HT fibers present the highest values of extension at failure (Figure 4). The influence of pre-loading on extension is more significant.

As it can be seen in Figure 5, the modulus of elasticity increases when the pre-load is increased from 25 to 100 N. The carbon reinforced fabrics present the highest modulus of elasticity.

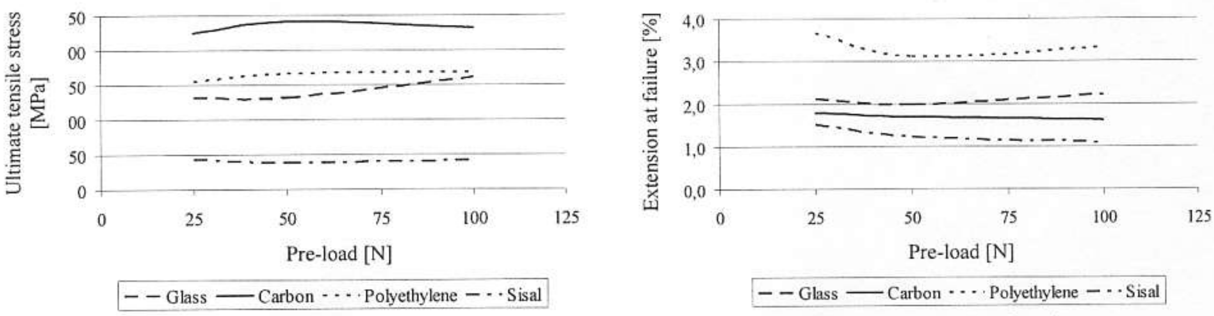

Figure 4: Influence of initial pre-load on the ultimate tensile stress (mean values).

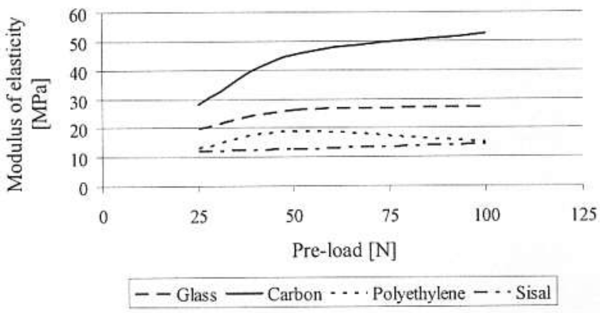

Figure 5: Influence of initial pre-load on modulus of elasticity (mean values).

The effect of initial pre-loading of the core reinforcement braided fabrics presents a significant influence on their modulus of elasticity, as can be seen by analysing the core reinforced braided fabrics tensile behaviour (Figure 6).

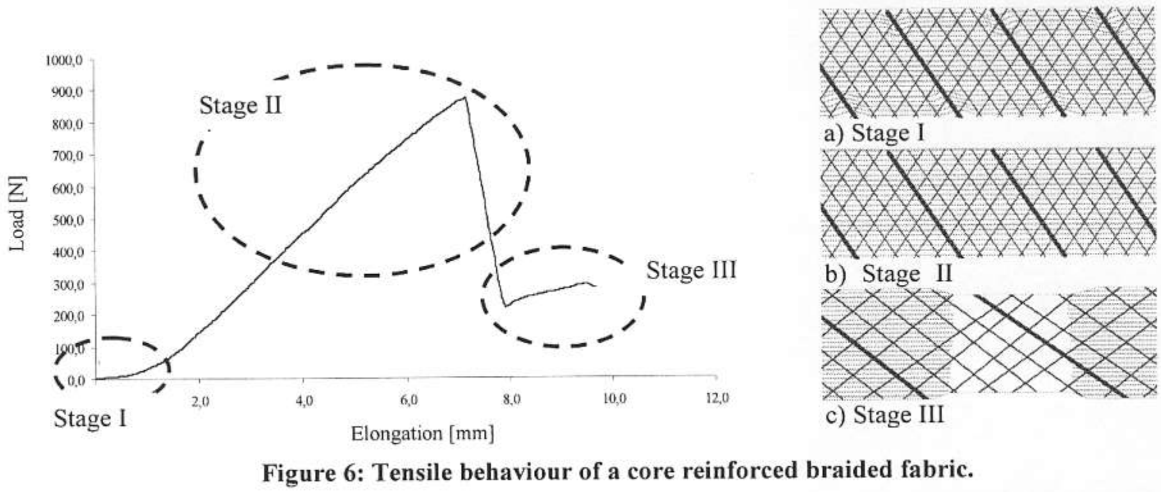

Figure 6: Tensile behaviour of a core reinforced braided fabric.

Three stages can be identified in the load-elongation curve for a core reinforced braided fabric: **Stage I** – The load is supported by the core reinforced fibers; even though, the fibers are not yet completely straight (Figure 6 a)); **Stage II** – The reinforcement fibers are now completely straight and the load is supported by the core reinforced fibers. There is a significant increase in the load required to stretch the reinforcement fibers to the breaking point (Figure 6 b)); **Stage III** –The braided fabric starts to bear the load due breaking of the core reinforcement fibers. Even though braided structures present much better tensile properties comparatively to compressive ones, elongation is much higher than that present by fiber rovings (Figure 6 c)).

2. 3. Braided reinforced composite rods

Braided reinforced composite rods have been produced on a vertical braiding machine with an incorporated impregnation system. Tensile and bending tests were carried out on core reinforced composite rods.

Braided fabric composite rods reinforced with carbon fiber present the highest ultimate tensile stress, on both pre-loading test conditions (Table 4). Regarding to extension at failure and modulus of elasticity, the best results are obtained when core reinforcement fibers are subjected to 25N pre-load. Composite rods reinforced by carbon fibers present significantly higher modulus of elasticity and one of the lowest extensions at failure. Braided fabric composite rods reinforced with carbon fiber present the highest bending stress and significant higher bending modulus (Table 5).

Table 4: Tensile test results for composite rods (mean values).

Pre-load [N]	Reinforcement fiber	Ultimate tensile stress [MPa]	Extension at failure [%]	Modulus of elasticity [GPa]
25	Glass	537,9	4,5	9,7
	Carbon	793,5	3,3	25,0
	Polyethylene	525,3	3,9	8,7
	Sisal	121,8	2,7	4,4
100	Glass	454,5	3,5	9,0
	Carbon	685,7	2,6	23,3
	Polyethylene	473,9	3,9	7,5
	Sisal	114,6	2,3	4,3

Table 5: Bending test results (mean values).

Reinforcement fiber	Bending stress [MPa]	Bending modulus [GPa]
Glass	161,0	5,9
Carbon	351,7	20,3
Polyethylene	115,8	4,1
Sisal	103,0	3,0

3. CONCLUSIONS

It was concluded that for a braided fabric structure there is a braiding angle that promotes the optimized mechanical performance of the core reinforced braided structure and. Analysing the test results obtained it is possible to identify different performances among the different types of core reinforced braided fabrics and the different types of braided reinforced composite rods. The trends in properties of core reinforced braided fabrics are similar to that of composite rods. The mechanical behaviour of the core reinforced braided fabrics is mainly dependent on the core reinforcement performance. It is also concluded that it is necessary to set a pre-tension on the reinforcement fibers to guarantee an optimized mechanical behaviour of core reinforced braided fabrics.

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